Maintenance Project of a Petroleum Platform using CCPM.

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***Abstract* — Petroleum platforms require highly maintenance in their structure, mainly due to the risks involved to the activities in which they are framed. The name of that kind of maintenance is scheduled shutdown. Nowadays companies seek to reduce the plant production stop to maintenance execution due to the costs and risks involved in those activities. This study aim to present the project to a scheduled shutdown under the theory of constraints (TOC) perspective, comparing the critical chain methodology (CCPM) with the traditional critical path method (PERT/CPM). The enforcement of CCPM translated into runtime reduction in project execution, reflected directly in the reduction of the costs. The application of TOC results in scale gains for the company by reducing the execution period and cost.**

***Index Term*— Theory of Constraints (TOC), Scheduled Shutdown Maintenance, Critical Chain Project Management (CCPM), Petroleum Platform, Critical Path Method (PERT/CPM),**

I. Introduction

In an economy marked by fierce competitiveness, companies seek productivity gains through technological innovations and by the adoption of new organizational models [29]. In a globalized world, the companies must be well prepared, increasing their competitiveness to face the competition [55].

Some of the prerequisites for the survival of organizations in this highly competitive environment is the agility, the ease of adaptation, implementation of strategies and the ability to offer new products and services [67]. One of the project management characteristics should combine human and material resources at the speed required by today's pace of change [19]. The construction sector, although being one of the largest economy sectors, has its own characteristics and that, despite its importance, it has major failures regarding the planning process [17].

From time to time, ideas or innovative theories emerge, designed to oxygenate the organizations and, thus, keep them in the race for survival in the market [52]. Thus, this study aims to demonstrate the advantages of the applicability of the critical chain methodology (CCPM) compared to the critical path method (PERT/CPM); to validate the assertion that the management of times or deadlines of the project is one of the most important processes, or the one which has greater influence and impact on results [20]. The project management purpose is to generate value for the organization and the way that it occurs is through the correct delivery in the content, cost and on time [52]. For example, during a production stop on an oilrig, up to 150.000 barrels of oil can be left to be produced per day, which means about US$ 7 million. The proposal of this study is to present the advantages in migrating from traditional methodology (PERT / CPM) to CCPM.

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II. Study Methodology

Regarding the methodology, it can be said that this study is an applied research because, it was motivated by the "need to solve concrete problems, immediate or not" [87]; that research is the rational and systematic process used in the search for answers to the problems [23]. Furthermore, this research is of qualitative type, for not using statistical tools in its analysis; Documentary, because it was based in reports and data collected about the studied company; Descriptive, because it "aims to describe the characteristics of a given phenomenon" [23]; Exploratory, because it searches deepening the subject for the theory application, deepening done through literature research about the addressed topic, whose sources were books, articles and scientific publications, national and international.

This study was accomplished through literature search based on studies on project management, the methodology for project time management (PERT, CPM and CCPM) and scheduled shutdown maintenance in oil platforms. With that information, it sought to trace a comparison of the advantages in the change of methodology because, time and cost management became even more critical due to traditional project management models, always presenting late date completion and budgets overrun [81]; Cavalcanti [11] increased this statement including that the finalized projects usually cannot reach the entire traced scope.

The PMSURVEY.ORG 2013 Edition [70] presented a research in which 44% of Brazilian companies in heavy construction with budgets bigger than US$ 10 Million extrapolate the budget and that 78% extend beyond the term. This research also identifies, as being some of the main problems in this sector projects, the constant scope changes, problems with suppliers, communication problems, ill-defined responsibilities and not adequately evaluated risks. [36].

III. Materials and Methods

Preventive maintenances aim to avoid or reduce the consequences of failure of certain equipment [59], validating the assertion that the main motivator of Scheduled Shutdowns Projects is a plant operating with reliability [44].

A. Project management

Projects involve the use of a wide range of project management practices and each company brings their own tools, techniques, methodologies and models [37]. Managing projects is one of the most serious problems in today's world and that, progressively, it will become the most important activity for companies and countries [14].

The project management began to take shape in the late 50's, being developed mainly for civil engineering, mechanical engineering and military projects [12]. The use of Project Management, guided by the perspective of the PMI is one of the most common practices and in its last review [29], the PMI [69] defines project management as the application of knowledge, skills and techniques. The main roles of project management are to ensure the completeness of scope, to ensure and control the quality, meet the delivery deadlines and above all to promote the growth of the organization or sector through change management and viabilization strategies [50]. The success of any project depends very much on the quality of planning, programming and the control of the various phases of the project [81].

It is extremely important for project managers to select the appropriate tool or technique [21]. In the project management environment, the time is more a restriction, and effective time management principles should be employed to make it a resource [38].

The present study was developed following this reasoning, with the focus to reduce the time of scheduled shutdown execution. The PMI [69] identifies the PERT / CPM (Program Evaluation and Review Technique / Critical Path Method) and the CCPM (Critical Chain Method) as the most popular methods in time management. As the application of the PERT/CPM methodology on maintenance environment of oil platforms has been already studied, the implementation of CCPM methodology will be addressed here.

B. Methodology PERT/CPM

The CPM was first used in 1956, in the Scheduled Shutdown of the DuPont factory, reducing the maintenance execution schedule from 125 to 78 hours [20]. He also states that this is probably the best-known and used technique in the time management of a project.

In 1958 the US Navy developed the PERT during the construction of the Polaris nuclear submarines [56]. In the essence the two methods, PERT and CPM are similar, because they identify the critical project activities as those that cannot be delayed and those that may change in its running time without affecting the fulfillment of the project term. Initially the PERT was used more for research and development projects and the CPM for construction projects [12].

In the schedule development phase of the project, several elaboration techniques of schedule of activities can be used; these include the Gantt's Graph and Mark's Diagram [20]. She also affirms that the CPM adopts a single time estimate for each activity, which is usually based on the experience of experts and on lessons learned in projects already undertaken. De Carvalho and Rabechini Jr. [18] emphasize that when making estimates in this way, they possess a high degree of uncertainty, including for the most experienced experts. In a synthesized form, the PERT method is based on the resultant of three time estimates for the project activities, which are the Most likely (M), the Optimistic (O) and the Pessimistic (P) [20].

In their study, Cooper Ordoñez [12] states that the PERT/CPM methodology is criticized for not providing the achievable conclusion dates and for using resources inefficiently [4; 40; 56]; but they continued to evolve, as observed in the studies [3; 39; 45; 48; 60; 78; 90].

As a starting point for comparison between the time management methodologies, this study will use the study of Alves [2]. He had applied the knowledge of PERT/CPM in planning the scheduled shutdown of the P-40 platform; in this study, the sequencing of activities for the production separator maintenance, which is the primary vessel which promotes the primary separation of oil, water and gas, are reported.

This sequence of activities has been identified as being the single critical path of the platform maintenance project and, based on this information, the Table 1 was elaborated, which beyond the values for the CPM and PERT calculation also shows the values of the Expected Activity Duration (EAD), the standard deviation (σ), the variance (V) and the Real Time (RT) obtained in performing each activity, without the use of the methodologies presented in this study.

As can be identified in the study done by Alves [2], there are no latencies or converging paths in precedence network, the critical path is obtained by summing the length of each task.

The estimates should be done by professionals who will perform the service, thus ensuring greater reliability to the estimated value [61]. The formulas presented below were used to obtain the values presented in Table 1, formulas which were ratified in other studies on planning techniques [2; 17; 61].

$$EAD = \frac{P+4M+O}{6} \quad (1)$$

$$\sigma = \frac{P-O}{6} \quad (2)$$

$$V = (\sigma)^2 \quad (3)$$

The standard deviation calculus for the project duration is similarly done to the activity standard deviation [2], but Mulcahy [61] states that it is not possible to sum the standard deviations of each activity, it is necessary to calculate the variances of activities and sum them; from the square root of this sum, we obtain the standard deviation of the project; for the studied example, it shows the value of 10.8 hours.

Table I
Critical Path Task - Database

ID	Critical Path Task	RT	CPM	PERT					
				O	M	P	EAD	σ	V
1	System release - depressurization	4,0	15,0	4,0	6,0	20,0	8,0	2,7	7,1
2	Water circulation by vessel	13,0	9,0	7,0	10,0	15,0	10,3	1,3	1,8
3	Electrical disconnect, tubings and capillaries	2,0	2,0	1,0	2,0	4,0	2,2	0,5	0,3
4	Vessel Shutdown	8,0	15,0	7,0	9,0	16,0	9,8	1,5	2,3
5	Inerting the vessel with steam	21,0	22,0	21,0	22,0	30,0	23,2	1,5	2,3
6	Cooling	13,0	10,0	8,0	10,0	15,0	10,5	1,2	1,4
7	Open manholes and removing spools	8,0	11,0	6,0	7,0	11,0	7,5	0,8	0,7
8	Ventilate and free for entry – Confined space	10,0	4,0	2,5	3,0	8,0	3,8	0,9	0,8
9	Central Chamber– Cleaning	1,5	8,0	2,5	3,0	20,0	5,8	2,9	8,5
10	Disassemble water and oil vortex breaker	1,0	1,0	0,5	1,0	2,5	1,2	0,3	0,1
11	Assembling scaffolding in the central chamber	0,5	1,5	0,5	1,0	2,0	1,1	0,3	0,1
12	Wash demister and fillings with pressure washing	1,5	4,0	1,0	2,0	7,0	2,7	1,0	1,0
13	Inspection of structured fillings and demister	1,0	3,0	3,0	4,0	5,0	4,0	0,3	0,1
14	Disassembling the demister	1,0	3,0	1,0	2,0	4,0	2,2	0,5	0,3
15	Chamber 1 - Clean and Remove baffles	65,0	52,0	20,0	45,0	70,0	45,0	8,3	69,4
16	Dismantle and Remove structured fillings	23,5	25,0	10,0	15,0	25,0	15,8	2,5	6,3
17	Assemble demister	3,0	6,0	4,0	5,0	6,5	5,1	0,4	0,2
18	Mounting structured fillings	7,0	21,0	8,0	10,0	24,0	12,0	2,7	7,1
19	Disassembling scaffolding	1,5	2,0	1,0	2,0	2,5	1,9	0,3	0,1
20	Assemble water and oil vortex breaker	1,5	2,0	1,5	2,0	2,2	2,0	0,1	0,0
21	Inspect assembly of the internal parts of the vessel	0,5	2,0	1,5	2,0	4,0	2,3	0,4	0,2
22	Mount baffles	15,0	20,0	8,0	13,0	18,0	13,0	1,7	2,8
23	Turn on the vessel, reassemble spools and closing BVs	6,5	18,0	5,0	8,0	17,0	9,0	2,0	4,0
24	Perform controlled torque	0,5	5,0	2,0	3,0	4,0	3,0	0,3	0,1
25	Connect Electric, tubings and capillaries	2,5	1,0	1,0	2,0	2,5	1,9	0,3	0,1
Sum		**212,0**	**262,5**	-	-	-	**203,0**	-	**116,8**
Square root		-	-	-	-	-	-	-	**10,8**

Do Carmo et al [22] present the maturation process in the use of TOC through publications over time, starting with "The goal"[25]; "The Haystack Syndrome" [27]; "It's not Luck" [26] and "The Critical Chain" [28]. They also prepared a summary of the various applications of this knowledge in areas beyond the business environment and following this reasoning, this study aims to deepen the knowledge through the applicability of the CCPM methodology in planning the scheduled shutdown of an oil platform, based on data from the study which Alves [2] accomplished with a focus on PERT / CPM planning methodology.

CCPM History: The Critical Chain Project Management (CCPM) is how the application of the Theory of Constraints in Project Management is called. [14]. This new aspect of project management has received greater attention in the literature after the publication of the book "The Critical Chain [28]" [20]; to show this statement the author lists some publications in books [42;63] and articles [9; 24; 32; 41; 66; 84] that were written to clarify and discuss this theory.

Luiz [49] mentioned that, like any methodology, publications that accept its applicability can be found [5;8;47;; 72;79; 83; 85]; as well as the ones which question it [33;34; 43]. He also reports that some authors [54; 73] question the methodology of CCPM regarding its innovation, because according to them, the same consists of concepts already known and are only presented with a different formatting, contrasting the described by Lechler [43] who identified in the publications of Steyn [80] and Newbold [63] the statement that the CCPM is the direction for the project management in the XXI century. Luiz [49] reports that some authors have exploited the CCPM tools through analytical and mathematical methods, demonstrating that methodology is mature as a project management tool [35; 51; 91].

In his study, Ordoñez [12] produced a survey of the leading publications in Brazil and found that the practical applications or simulations appear since 2004, indicating a greater interest of the scientific community about the validity of the method.

CCPM methodology: According to Couri [14], based on the TOC principles, Goldratt and Cox [25] elaborated a list of five steps which aim to direct the focus and the efforts in the optimization process continue. The five steps and its main characteristics are: [2; 20; 71; 89].

Step 1 - identify the constraint; it is considered that the whole system will have at least one constraint to be identified and if it can be eliminated, there is no need to perform the remaining steps. Resources limitations and the logical dependencies to complete a project are considered as constraints. According to TOC, the entire system has at least one constraint, because if there were not anything to limit the system performance, its income would be infinite [13; 57].

Step 2 - explore the constraint: maximize its use to obtain the best possible result in this condition [31]. That way it is taking full possible advantage of the resource that restricts the system [57].

Step 3 - subordinate the rest of the activities to the constraint: Csillag and Corbett [16] indicate that other resources must work at the pace of the constraint, not faster nor slower.

Step 4 - raise system constraints: where you must act to increase the capacity of the primary constraint, by investing in hand-to-work contracts, equipment purchases, working more shifts. [1; 64].

Step 5 - Identify the new constraint: If at any previous step the constraint is broken, it is necessary to go back to Step 1, because whenever a constraint is eliminated, another will appear in the system [20]. You should repeat the five steps as a systemic and dynamic process [16; 57].

Security mechanisms: All tasks are performed by people, whether they are tasks of technical, physical, technological or financial nature; and that it is common to estimate the time of activities, insert safety margins in the projects to meet the uncertainties inherent to them [14]. The project delays also occur due to other elements that consume security: the "Student Syndrome" and the "Parkinson's Law" [65]. [6; 7; 28; 57; 74].

The "Student Syndrome" refers to the natural human tendency to wait until the tasks become extremely urgent to start them, that is, when there is time available, he leaves the beginning of the task execution near to the end of the estimated period [7; 46; 75].

The "Parkinson's Law" [65] describes that when you have time available, the work extends to fill the estimated time, even if the task is completed before the deadline, that is the resource will use all remaining time to finish the job task already completed. [7; 14; 20; 46].

Another safety consumer identified by Goldratt [28] is the harmful multitasking that occurs when the same resource is disputed by different projects or for different activities in the same project [12;20; 56; 68]; complements that this form of program aims to reduce the time of resource inactivity, but instead of contributing to the accomplishment of the deadlines, it ends up causing delays. When Goldratt developed the theory of Critical Chain, he suggested resizing the durations of tasks [42], with a relative reduction to the level of completion probability of 50%, and not 90% to 95% due to estimates done with large safety margins [20].

The main changes brought by the CCPM are related to cultural changes in project planning, as there is a reduction in the estimated time of activities between 30 and 50%, aiming to reduce the effects of Parkinson's Law [65] and the possibility of procrastination of activities execution, being by the effect of the student or by the harmful multitasking syndrome [62].

Estimation of the lungs: In a highly competitive market, the correct sizing of the reserves is an extremely important process, because if overestimated, it increases costs and make the project less competitive [77]. However, if undervalued it may result in delivery delays.

As a way to control the possible deviations without losing the term of the project [20], Goldratt [28] proposed the inclusion of time lungs at the schedule strategic points, so as to absorb the impact of unforeseen events, that may or not cause delays in the project; Lungs, those arising from the withdrawal of the safety margins of its own activities and included in lungs at the end of the chains limited by resources. [5; 12]. This is one of the largest CCPM contributions to projects management [15].

According to Mulcahy [61], the formulas (1), (2) and (3) refer individually to activities, to calculate the expected duration of a project it is necessary to estimate the individual durations of critical path activities and sum them. There are several sizing methods of the lungs [10].

The 50% Method: The method was proposed by Goldratt [28] and consists of removing 50% of the estimated duration for each activity and placing the removed 50% at the end of the current Critical Chain. The time to be used should be the pessimistic estimate, but that there are variations of the method using the sum of the difference between the pessimistic estimate and the average (EAD) [76]. Moellmann [57] reports that, this way, the lung will comprise about one-third of the project total time and this will lead the adjusted total duration to be equal to 75% of the originally estimated total duration time [63]. Although this method is simple, it has the disadvantage of not allowing accounting the existing variations in planning and to scale out overmuch high time reservations. [82].

Based on this information, for this study, it was obtained then, the lung value of 50.8 hours.

Root Square Error Method (RSEM): Another way to calculate the lungs is the Root Square Error Method and that this is based on two tasks duration estimates for the calculus of the lung size [86]. For the calculus, the Pessimistic estimates are necessary by having a fulfillment forecast of compliance of 95% and it is also identified as of low risk and the More Likely
that has a realistic security insertion or even without any protection, which will lead the team to do its utmost to carry out the activity in the given time [20]. This method is preferable because it has a more scientific approach, which allows accounting the existing variations in the planning of projects, but it has the disadvantage when used in long chains, it can present an undersized reserve [15]. Based on past experience this method has not proven to be more effective than 50-50% method [15].

The method of two standard deviations proposed by Newbold [63] has the following formula: [10; 53; 76].

$$Lung = 2x\sqrt{\sum_{i=1}^{n}\left[\frac{(Pessimistic_i - More\ Probable_i)}{2}\right]^2} \qquad (4)$$

The result obtained for this study using the RSEM method was 42.0 hours.

Square Root of the Sum of the Squared Deviations Method (SQR): According to Leach [42], this method uses the same statistical basis of the PERT technique, but it works only with the values of the Optimists and Pessimists estimates.

The SQR combines the two methods mentioned above, using the way of counting the variations of the first and the way to prevent the variations of the second [10].

The formula for the lung calculus using this method is shown below:

$$Lung = \sqrt{\sum_{i=1}^{n}(Optimist_i - Pessimist_i)^2} \quad (5)$$

Using the SQR method, the value obtained was 64.8 lung hours.

IV. Results and Discussions

The projects management involve making some estimates, and all estimates, even with a good basis, involves a degree of uncertainty [58]. The uncertainty is a common characteristic in project management [46].

Using the data in Table 1, with the value obtained in PERT as a reference, the range between the values of 138.2 and 267.8 hours for a confidence level of 99.99985% is obtained, that is, six standard deviations (6σ). In Table 2, it is important to note is all the values found for the project time, in the case of CCPM, including the estimated lung in each of the methods, are within the confidence interval range. It was also noted the ratification of the statement made by Nazareth [62] of reduction between 30% and 50% of the activities estimated time.

Another point to be highlighted is that even if the execution has not followed any of the methods presented in this study, only the CPM has superior time than RT.

A dynamic and flexible system is a form of protection to the project planning against political constraint, which according to Wanderley & Cogan [88] is the constraint formed by rules, procedures and usual practices of the past. The other constraint, is the one that includes market, supplier, machines, materials, order, project, people, and was named as a resource constraint [30]. What is one of the great challenges in this industry, because it refers directly to the training of new workers, especially in function of the personnel turnover, direct impact on the execution time [37].

Table II
Total time estimated by methodology.

	CPM	PERT	CCPM			RT
			50%	RSEM	SQR	
Hours	262,5	203,0	152,3	143,5	166,3	212,0
%Rel	-	23%	42%	45%	37%	19%

Source: Authors (2016)

V. Conclusion

As a final evaluation, it can be considered that the use of CCPM methodology is satisfactorily applicable to the studied case. The Critical Chain can contribute to projects management in maintenance of scheduled shutdowns on oil platforms. Furthermore, it was found in the current literature, few studies dealing with this specific subject. In this sense, the present study, at the same time it is seeking to contribute to increase knowledge in project management, it brings attention to the need for further study, especially if taken into account that each day without an oil platform production costs about US$7 million and that the estimated reduction in this study is at least of 4 days.

This work enabled the development of a greater knowledge regarding the Critical Chain, and may additionally contribute to the practical implementation of the presented proposal and its respective analysis.

Among the main benefits there are the pursuit of developing a more realistic schedule and consequently, with a smaller execution time. A more dynamic and flexible system that allows scope changes until an earlier date of the shutdown execution can also be developed, without prejudice to the schedule, because in the environment in which this study was carried out, the changes are constant, causing the consumption of large investments of resources, materials and time.

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FOOTNOTES

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